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# RESULTS OF OZONE OBSERVATION FROM THE EQUATORIAL REGION TO ANTARCTICA IN 1987

Kouji MATSUBARA[1], Motohisa DOI[1], Tetsuro UEKUBO[1], Kenji OKADA[1], Shuhji AOKI[2] and Sadao KAWAGUCHI[2]

[1]*Japan Meteorological Agency, 3–4, Otemachi 1-chome, Chiyoda-ku, Tokyo 100*
[2]*National Institute of Polar Research, 9–10, Kaga 1-chome, Itabashi-ku, Tokyo 173*

***Abstract:*** The first total ozone observation and vertical ozone sounding on board the research vessel 'SHIRASE' from the equatorial region to Antarctica was carried out in 1987 by meteorological members of the 29th JARE (Japanese Antarctic Research Expedition) team. Total ozone and vertical ozone profile were measured by Brewer ozone spectrophotometer and ozonesondes, respectively.

The detailed latitudinal distribution of total ozone amount and height-latitude distributions of ozone concentration, temperature and wind at 5-degree latitude intervals from the equatorial region to the Antarctic region were observed. From the ozonesonde observations, the injection of ozone from the stratosphere to the troposphere through the tropopause gap was deduced. The decreased ozone concentration in the lower stratosphere, similar to as same as the Antarctic ozone hole, was observed south of 60°S. It is possible that this phenomenon was caused by transport of ozone-poor air (a 'dilution effect') following the spring time ozone hole.

## 1. Introduction

Recently, CHUBACHI (1984) has reported extremely low total ozone amount from September to October at Syowa Station and also Amundsen-Scott Station during 1982.

FARMAN *et al.* (1985) have also reported a rapid decrease of total column amount of ozone in late winter and early spring over Halley Bay Station. They attributed this decrease of total ozone to increase in stratospheric chlorine due to chlorofluorocarbon release, and proposed that the unique conditions of extreme cold and low sunlight in the Antarctic winter and spring enhanced the effect.

SOLOMON *et al.* (1986) noted that extreme cold temperatures in the Antarctic winter and spring lead to greatly enhanced polar stratospheric clouds (PSCs) occurrences. They suggested that there are heterogeneous reactions on the surface of PSCs. Ozone depletion could then be expected to occur in the spring, when sunlight is again available to drive photochemical effects following such perturbations due to PSCs.

STOLARSKI *et al.* (1986) presented total ozone measurements from 1978 through 1986 from the TOMS (Total Ozone Mapping Spectrometer) instrument and revealed Antarctic ozone depletion over a very extended area, in general agreement with the local ground-based data.

After the discovery of the spring Antarctic ozone hole, intensive measurement programs were carried out in the Antarctic region. It is important for understanding the Antarctic ozone hole phenomenon and its effect on the global ozone change to observe the ozone hole mechanisms not only over the Antarctic region, but also the surrounding region. There are a few ozone observing stations in the southern hemisphere, especially in the Antarctic region. The information regarding the latitudinal vertical profiles of ozone, temperature and wind perturbation is useful to understand the chemical and dynamical processes controlling stratospheric ozone content.

The first set of ozone observations on board the research vessel 'SHIRASE' from the equatorial region to Antarctica was carried out in 1987 by the meteorological members of the 29th JARE team for comparison with model calculations of the global distribution of atmospheric ozone, for serving as a priori statistical information in deriving ozone vertical distributions from satellite.

In this paper, we would like to describe the total ozone amount by use of ozone spectrophotometer and the vertical profile of ozone concentration, air temperature and wind by use of ozonesonde from the equatorial region to Antarctica. Collected data were published by the JAPAN METEOROLOGICAL AGENCY (1990).

## 2. Instruments and Observations

### *2.1. Total amount of ozone*

Total ozone amount was observed with a Brewer ozone spectrophotometer (KERR *et al.*, 1984), No. 034 and deduced from observations on direct sun or zenith sky. It was important to protect the exposed equipment from rolling and pitching of the ship, and wetting by rain and sea spray. In addition, it was important to consider ease of handling and measurement. The Brewer ozone spectrophotometer satisfies these conditions, it is compact, waterproof and automated. The zenith sky observation was made automatically, the direct sun observation by pointing the equipment manually toward the sun. Observation errors due to rolling and pitching of ship were assumed less than 2% (1 standard deviation). Observations were made almost daily from November 16 to December 20, 1987 (26°N to 70°S latitude). Intercomparisons for calibration were made with the Dobson spectrophotometer, Beck 116 at Tateno before and after the voyage, and also at Syowa Station with the Beck 122.

### *2.2. Vertical ozone profile*

Vertical distributions of ozone concentration, air temperature and wind profile were observed with ozonesonde of electro-chemical type (KI solution, platinum and carbon electrode), Meisei KC-79 which was a modified version of the KC-65 (KOBAYASHI and TOYAMA, 1966). The ozonesonde signal was received through the automatic direction finding system equipped the research vessel 'SHIRASE'. Ozonesonde soundings were carried out 20 times and 18 profiles were successfully collected. The ozonesonde data were corrected by the total ozone amount data obtained with the Brewer ozone spectrophotometer.

Figure 1 shows the ozonesonde observation points. The ozonesonde observations were executed almost daily along 110°E from November 19, 1987 to December 7, 1987 except during a stay in Fremantle, and every days from December 10, 1987 to

December 14, 1987 on the voyage toward the west. The data were obtained about every 5 degrees of latitude.

## 3. Results and Discussion

### *3.1. Latitudinal change of total ozone*

Figure 2 shows the latitudinal variation of total ozone amount from the equatorial

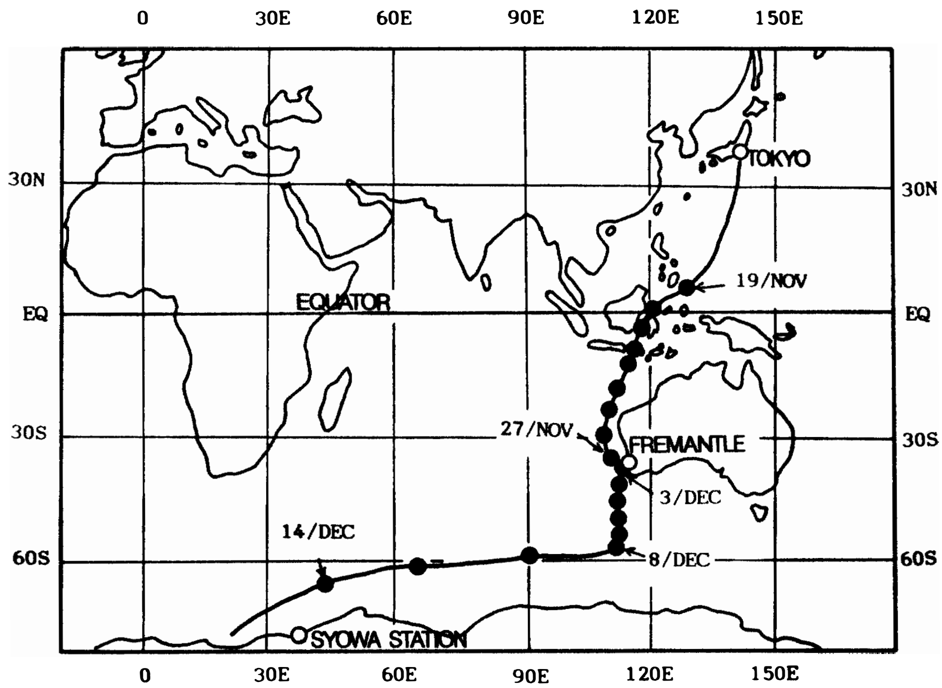


*Fig. 1. Observation points of ozonesonde (solid circle) along the course of 'SHIRASE' voyage from Tokyo to Antarctica.*

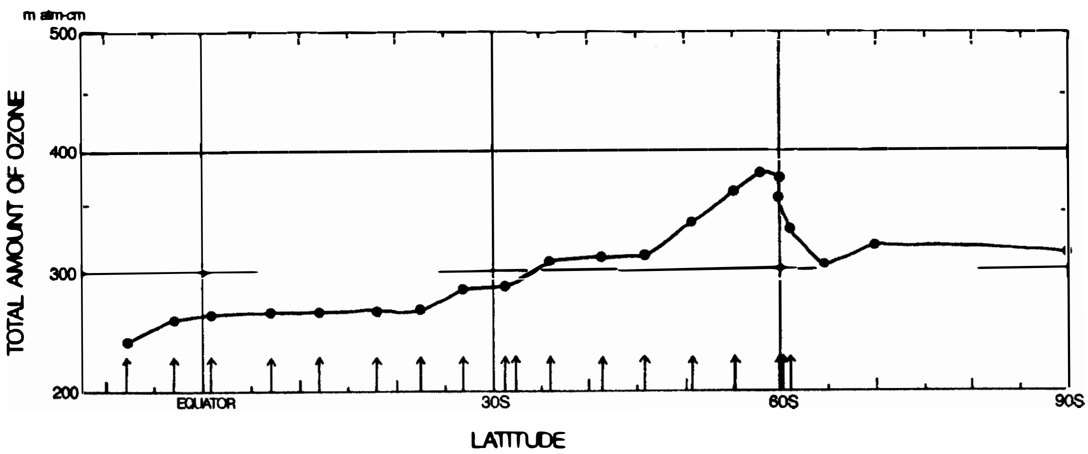


*Fig. 2. Latitudinal variation of total ozone amount from equatorial region to Antarctic region. The data at 70°S and 90°S were taken from observations on December 12 at Syowa Station (JAPAN METEOROLOGICAL AGENCY, 1989) and at South Pole (KOMYHR et al., 1988), respectively. Arrows show ozonesonde observation points.*

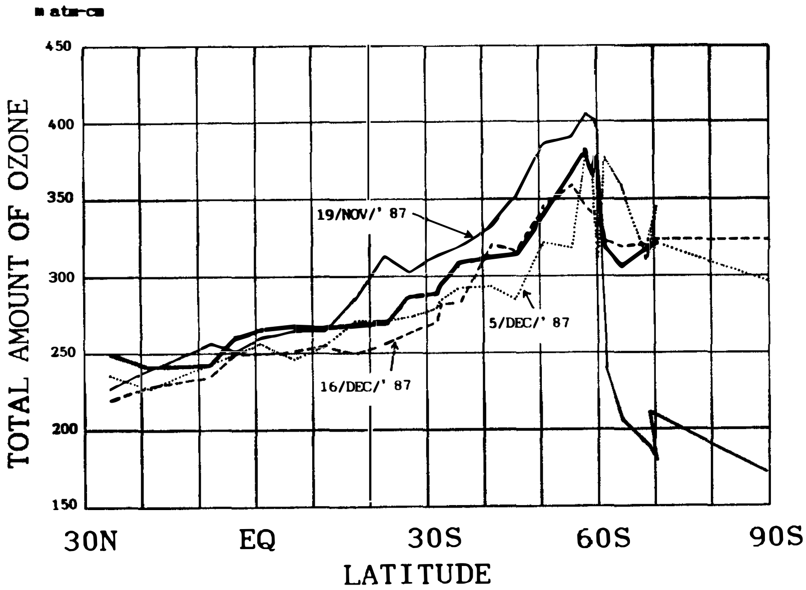


*Fig. 3. Comparison of total ozone amount (in units of m atm-cm) with Nimbus-7 Total Ozone Mapping Spectrophotometer (TOMS) data. The bold solid line shows our observations; other data are the grid point values of TOMS on the course of the 'SHIRASE' voyage on November 19 (solid line, when the first ozonesonde observation was made), December 5 (dotted line, the middle day) and December 16 (dashed line, the last day).*

region to the Antarctic region. There is a minimum value at about 7°N. Two gradual increase zones correspond to the latitude ranges 8°N to the equator and 23°S to 36°S. An abrupt increase and decrease are seen around the 60°S maximum. Total ozone amount was low south of 60°S.

Although our observations were taken only once, but it is important to consider whether the data are representative of the season and the latitude, especially when discussing the latitude-height cross section taken by ozonesonde. Figure 3 shows a comparison between our results and the TOMS's grid point value of total ozone amount on the first (19/NOV), mid- (5/DEC) and last (16/DEC) day of the observation period. From this figure, our results show the representative latitudinal variation in this season except for the deep ozone hole that occurred south of 60°S on the first day.

### *3.2. Latitude-height variations of partial ozone pressure and its relation to meteorological variables*

Figure 4 shows the latitude-height cross section of ozone partial pressure and air temperature observed by ozonesonde. In this figure, contours of both equal ozone partial pressure and air temperature slightly descend toward the south. A high ozone partial pressure zone greater than 150 nb appears over the equatorial zone and south of 40°S; its height declines to the south, too. There were two low air temperature zones. One colder than −80°C, appeared around the tropopause at the latitudes from the equator to 20°S; the latter, colder than −60°C, appeared from the tropopause upward at latitude 62°S. The zone colder than −80°C coincides with a zone of constant total ozone amount in Fig. 2. The tropopause slightly descends to the south.

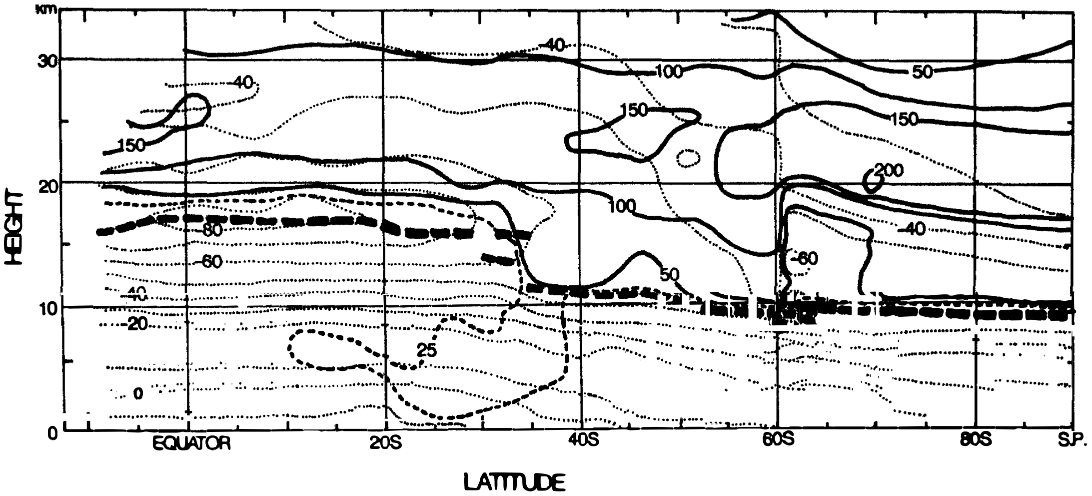


*Fig. 4. Latitude-height cross section of ozone partial pressure (solid and dashed lines, in units of nb) and air temperature (dotted line, in units of °C). The bold dashed line shows the tropopause. Data at 70°S and 90°S are the same as in Fig. 2.*

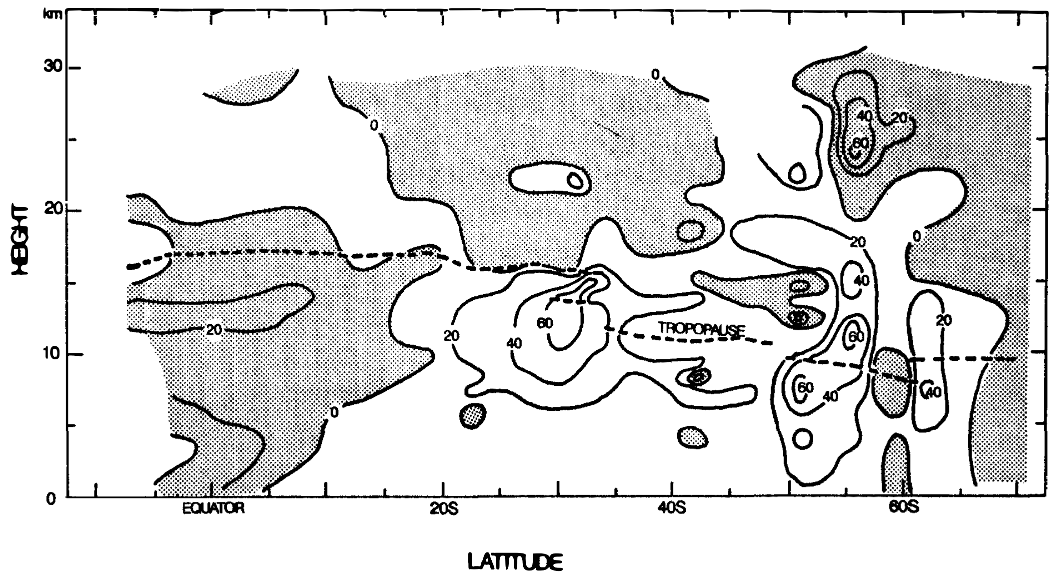


*Fig. 5. Latitude-height cross section of east-west upper wind component (m/s). The shaded area shows the area of prevailing easterly wind.*

There are two large gaps and one small gap, which appear in the latitudes range from 30°S to 35°S and around 61°S, around 50°S, respectively. The two large gaps correspond to an area of slightly increasing ozone concentration in the troposphere from 23°S to 36°S and a zone of abruptly decreasing ozone concentration in the stratosphere around 60°S. Especially around 60°S, it was too difficult to draw the contour because of an abrupt height rise from 10 to 20 km. In the area around 60°S there were seen temperature below −60°C and low ozone partial pressure in the height range from 10 to 20 km and latitude range from about 60°S to 70°S.

Figures 5 and 6 show latitude-height cross sections of the east-west and south-north upper wind components, respectively. In Fig. 5, there are two strong zones of

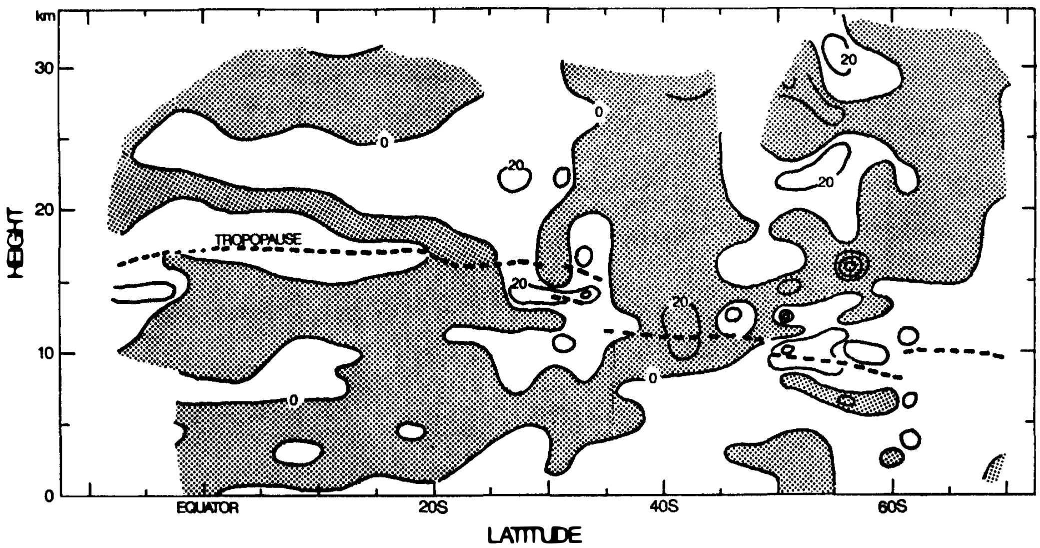


*Fig. 6. Latitude-height cross section of upper wind north-south component (m/s). Shaded area shows the area of prevailing northerly wind.*

westerly wind stronger than 60 m/s. The former is around 30°S, which coincides with the strong southerly wind zone shown in Fig. 6, the latter is in the region from 50°S to 56°S. There is strong easterly zone at 57°S which at a height of about 25 km in the stratosphere. From Fig. 6, there are four distinct regions of north-south wind component in the stratosphere with boundaries at around 35°S, 45°S and 60°S. These boundaries coincide with boundaries of regions of increasing or decreasing total ozone amount as shown in Fig. 2. Comparing Fig. 4 and Fig. 5, in the tropopause gap from 23°S to 36°S there blew a westerly wind more than 60 m/s as shown Fig. 5. The 25 nb ozone partial pressure contour line in the troposphere spreads south of the strong westerly wind. Many researchers, *e.g.*, SHIMIZU (1960), have suggested that increase of total ozone amount occurs north of the strong westerly wind (jet stream) in the northern hemisphere (south in the southern hemisphere); and an injection was seen from the stratosphere to the troposphere through the tropopause gap. Our result shows the scale and amount of injection in the southern hemisphere from the stratosphere to the troposphere which has not been reported previously.

### *3.3. Comparison of vertical ozone concentration profiles from the total ozone maximum point to Syowa Station*

Figure 7 shows the variation of the vertical ozone partial pressure profile in the region from the total ozone maximum point to Syowa Station. The zone of abrupt decreasing total ozone amount coincides with the decrease of ozone partial pressure in the height range from 10 to 20 km at 61°06′S, 42°18′E and from 10 to 18 km at 69°00′E, 39°35′E (Syowa Station). There have been many reports on the relation between total ozone amount and stratospheric temperature in the ozone hole seasons. KONDOH *et al.* (1987) pointed out that from ozonesonde observation at Syowa Station in the spring ozone hole season ozone partial pressure and temperature are lower than normal in the height range from 10 to 25 km. The height of low ozone partial pressure in

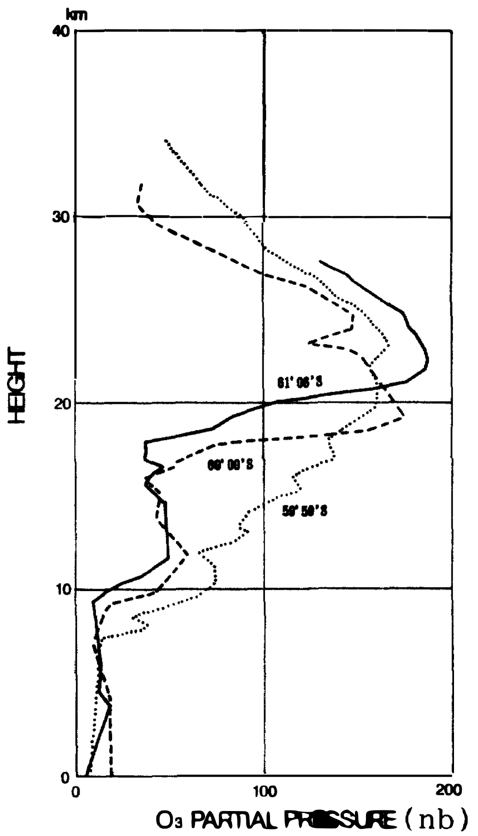


*Fig. 7. Vertical profiles of ozone partial pressure in the region from the total ozone maximum point to Syowa Station. Vertical profiles at 59°59′S, 89°35′E (dotted line), 61°06′S, 42°18′E (solid line), and 69°00′S, 39°35′E (dashed line, at Syowa Station) are illustrated.*

this work approximately coincides with their result. From this evidence, it is possible that an Antarctic ozone hole existed in mid-December, 1987.

### *3.4. Low ozone concentration in the lower stratosphere from 60°S to 70°S*

Many researchers have studied the so-called "dilution effect" by model calculation *e.g.*, SZE *et al.* (1989). SZE *et al.* studied the post-ozone hole impact on the spatial and temporal distributions of column ozone at latitudes north of 60°S using a two-dimensional model. They suggested that the time constant associated with the dilution effect in the latitude region 40–60°S is 1 year, long enough to contribute to the observed year-round decrease of total ozone in that region.

ATKINSON *et al.* (1989) suggested from TOMS data that there were two bands of total ozone reduction in mid-December, 1987. One band extended across southern New Zealand and southern Australia; the other across southern of Africa and southern South America. From this fact, they pointed out that transport of ozone-poor air reached 32°S in the Australia-New Zealand area in December 1987 following the lowest springtime ozone values ever observed over Antarctica, and the Dobson data record exhibited a sudden drop in mid-December across southern Australia and New Zealand to about 10% below normal December values, which lasted for the rest of the month. December mean ozone in 1987 was the lowest ever recorded at Melbourne. The timing of this sudden drop coincided with the final breakdown of the polar vortex in the lower stratosphere.

KANETO *et al.* (1990) reported from upper air observations in 1987 at Syowa Station that monthly stratospheric air temperature in 1987 was lower than normal. They also reported that the breakdown of stratospheric polar night jet broke down in December, one month behind normal year.

The monthly mean total ozone in December, 1987 at Syowa Station was about 10% below normal (1961–1980). Figure 8 shows the same TOMS total ozone difference between three-day means centered on December 8 and December 14 according to ATKINSON *et al.* (1989). Our observation period, especially from December 8, 1987 to December 14, 1987 coincided with the period during which, they pointed out, the ozone reduction band ran across southern of Africa to southern South America.

Figure 9 shows a longitude-height cross section of ozone partial pressure and air temperature deduced from ozonesonde observations roughly along 60°S. In Fig. 9 low ozone partial pressure and air temperature occur in the lower stratosphere (height range 10–15 km) at longitude 67°E; the top height of low concentration (50 nb) and temperature (−50°C) rises from 15 to 18 km at longitude 42°E (north of Syowa Station). The observation of the north-south upper wind component at longitude 42°E showed that southerly wind was dominant from the surface to the lower stratosphere. Ozone thicknesses in the height range 10–19 km deduced from ozonesonde observations were

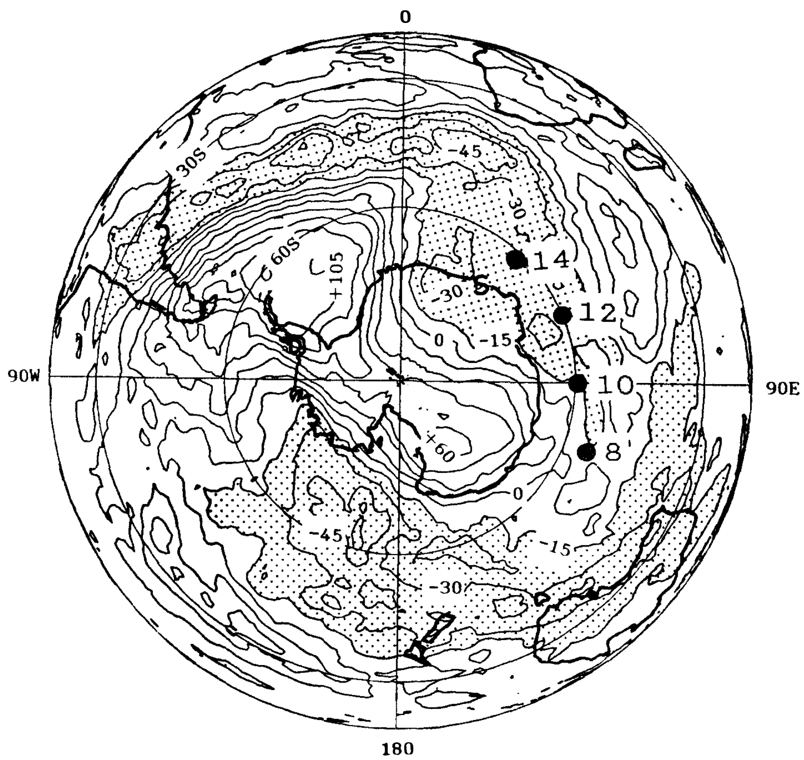


*Fig. 8. TOMS total ozone difference (in units of m atm-cm) between three-day means centered on December 8 and December 14. Shading denotes reduction greater than 15 m atm-cm. Solid circles denote the observation points of our ozonesonde in the period from December 8 to 14. The symbol "S" shows the location of Syowa Station.*

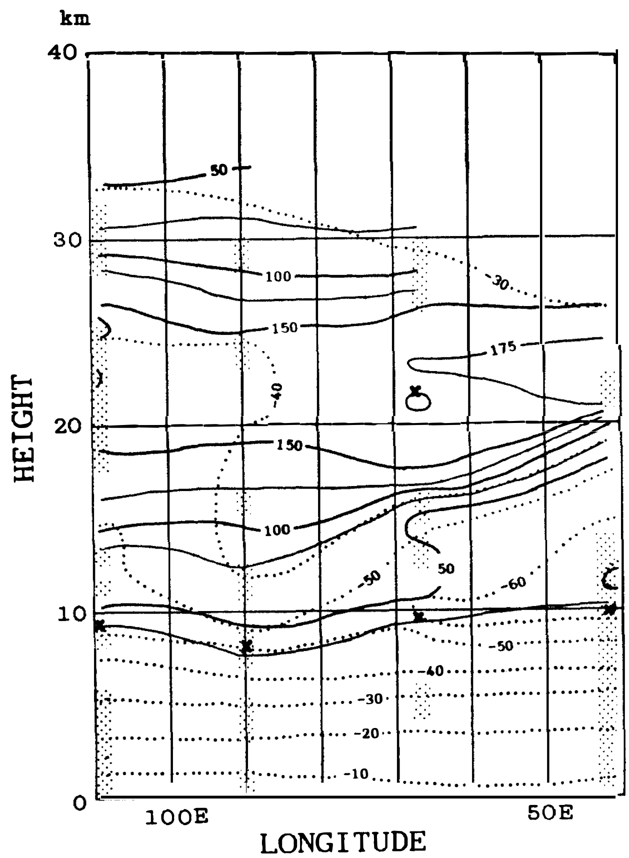


*Fig. 9. Longitude-height cross section of ozone partial pressure (solid line, in units of nb) and air temperature (dotted line, in units of °C). Crosses denote the tropopause. Shading denotes the area of prevalent southerly upper wind.*

106 m atm-cm on December 8 and 47 m atm-cm on December 14. The difference of thickness between those days was 59 m atm-cm, which almost coincided with the difference of total ozone amount, 49 m atm-cm. From these evidences, low total ozone south of 60°S should occur due to the low concentration in the lower stratosphere. It is possible that low ozone concentration in the lower stratosphere (10 to 20 km) south of 60°S is affected by the dilution effect.

## 4. Concluding Remarks

Total ozone observation and vertical ozone sounding were carried out on board the research vessel 'SHIRASE' from the equatorial region to Antarctica in 1987 by the meteorological members of the 29th JARE team. Total ozone was observed with a Brewer ozone spectrophotometer from November 16 to December 20 (latitude range 26°N to 70°S). Vertical ozone, air temperature and wind profile were observed with an ozonesonde from the equatorial region to Antarctica. Ozonesondes were launched 20 times and 18 profiles were successfully collected.

Results are as follows:

1) The detailed latitudinal total ozone amount and vertical profile of ozone concentration, temperature and wind from the equatorial region to the Antarctic

region were deduced.

2) The injection of ozone from the stratosphere to the troposphere through the tropopause gap was observed. This result should suggest the scale and intensity of the injection phenomenon.

3) The decrease of total ozone amount south of 60°S was observed; it is explained by the low ozone concentration in the lower stratosphere, hence it is the same phenomenon as the Antarctic ozone hole. This result makes it possible to understand the 'dilution effect' involving transport of ozone-poor air following break-up of the springtime Antarctic ozone hole.

Our observations were continued by members of the 30th JARE team. Continuing observation should give the important information for understanding the transport mechanism of ozone from low latitude to the high latitude region.

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The total ozone map for the southern hemisphere was provided by Mr. K. AKAGI, Aerological Division of Japan Meteorological Agency.

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